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(71) Applicant *(for all designated States except US)*: UDDEHOLM TOOLING AKTIEBOLAG [SE/SE]; S-683 85 Hagfors (SE).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: SANDBERG, Odd [SE/SE]; Strandvägen 28, S-683 40 Uddeholm (SE). JOHANSSON, Börje [SE/SE]; Stålnackes väg 11, S-683 91 Hagfors (SE).

(74) Agent: HYNELL, Magnus; Hynell Patenttjänst AB, Patron Carls väg 2, S-683 40 Hagfors/Uddeholm (SE).

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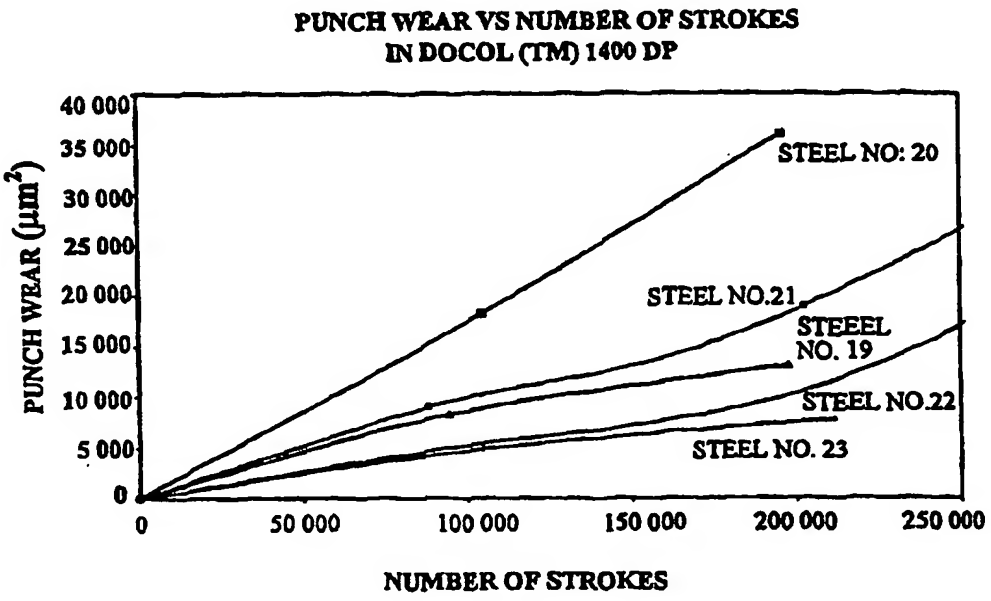
(54) Title: COLD WORK STEEL



(57) Abstract

A cold work steel has the following chemical composition in weight.%: 0.82–0.97 C, from traces to max. 1.10 Si, from traces to max. 0.62 Mn, at least 7.6 but less than 8.0 Cr, 2.30–2.70 Mo, 0.35–0.55 V, balance iron and impurities in normal amounts in the form of residual elements from the manufacture of the steel.

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COLD WORK STEEL

TECHNICAL FIELD

The invention relates to a new cold work steel, i.e. a steel intended for the manufacture of tools for cold working. Typical applications are blanking knives, punching tools, deep drawing moulds etc.

BACKGROUND OF THE INVENTION

The most important feature of a cold work steel is that it shall have a high hardness. For most applications also a good abrasion resistance and a toughness sufficient for the application are required. In order to satisfy these primary and a number of other requirements, a very great number of steel alloys have been developed. Most of these alloys, especially when toughness is more important than wear resistance, have a composition within the following alloying ranges: 0.8-1.2 C, 0.2-1.2 Si, 0.2-0.5 Mn, 5-12 Cr, 0.5-4 Mo, 0-3 W and 0.2-2 V. Further, small or moderately high contents of Ni, Nb, Cu and/or Al may be present. A steel of the latter type, which contains moderate though significant contents of niobium and aluminium, is described in US-A-5,160,553.

DISCLOSURE OF THE INVENTION

It is the purpose of the invention to provide a cold work steel with a chemical composition which is balanced such that the steel shall satisfy the following requirements:

- it shall be easy to manufacture in a non-powder metallurgical way and have a good hot workability in order to get a high yield in production;
- it shall be able to be manufactured in dimensions ranging from the very smallest dimensions, i.e. Ø 10 mm or less, up to Ø 500 mm or corresponding sizes in square or flat sections;
- it shall not contain any large amount of coarse primary carbides;
- it shall have good heat treatment features, which among other things means that it shall be able to be hardened from a moderately high austenitising temperature;
- it shall have a good hardenability, i.e. a capacity to be through-hardened also in case of large dimensions;
- it shall have good dimensional stability on heat treatment as well as in use, the latter condition *inter alia* implying that it shall have small susceptibility to ageing;
- it shall be able to secondary-harden in connection with tempering for the achievement of a hardness of 60-64 HRC;

- it shall have good surface deposition features, which means that it shall be able to be nitrided, case hardened and surface coated through PVD and CVD;
- it shall have good sparking machinability;
- it shall have an adequate abrasive wear resistance;
- it shall have an adequate toughness;
- it shall have a high compressive strength; and
- it shall have good fatigue features, good cuttability and good grindability.

First a series of cold work steels known in the art were examined. The chemical compositions of these steels are given in Table 1.

Table 1 Chemical composition, weight-%, of examined, prior art steels

Steel No.	C	Si	Mn	P	S	Cr	Ni	Mo	W	V	Nb	Ti	Cu	Al	N	O ppm	Bal.
1	1.0	0.22	0.53	0.020	0.001	5.48	0.13	1.14	0.01	0.19			0.09	0.036	0.022	15	Fe
2	0.80	0.89	0.40	0.025	0.001	8.23	0.14	1.94	0.008	0.50		0.012	0.07	0.016	0.022	8	Fe
3	0.98	0.95	0.40	0.025	0.001	8.32		2.01		0.26				0.010	0.015	15	Fe
4	0.95	0.94	0.44	0.015	0.001	8.26	0.36	1.84	0.02	0.45		0.005	0.03	0.020			Fe
5	1.09	0.80	0.41	0.018	0.001	8.26	0.46	2.14	0.05	0.51	0.12		0.19	0.91			Fe
6	0.95	1.0	0.5			8.0		1.5		2.0							Fe
7	1.0	1.0	0.4			8.0		1.5		2.0							Fe
8	1.12	1.20	0.30			7.75		1.60	1.10	2.40							Fe
9	1.15	0.25	0.23	0.22	0.005	11.51	0.29	1.39	2.62	1.56		0.002	0.10	0.003			Fe
10	1.50-1.60	0.10-0.40	0.20-0.45	max 0.030	max 0.0025	11.5-12.0	max 0.30	0.70-0.90	max 0.25	0.80-1.10			max 0.30	0.010-0.045	max 0.028		Fe
11	1.60	0.25	0.38	0.021	0.001	11.9	0.14	0.80	0.08	0.85					0.023	3	Fe

The steels of the table were examined or compared with reference to micro structure, including the type and character of inclusions, response to heat treatment, hardenability, hardness after austenitising and after tempering, dimensional stability, spark machinability, toughness in terms of impact strength and bending strength, abrasive wear resistance, compressive yield point, grindability, and cuttability.

None of the examined steels had an in all respects desired combination of features.

Then, during the continued development work, in view of the achieved results, a revised series of requirements was designed, wherein in the first place the influence of hardness and volume of carbides on toughness and wear resistance were considered. In this second phase of the development work it was examined more in detail how small changes in the contents of C, N, Mn, V, and Mo have influence on a number of such critical features as toughness, response to heat treatment, hardenability, secondary hardening, resistance to tempering, and wear resistance. In this work, there were made seven 50 kg laboratory heats with a chemical composition in weight-% according to Table 2.

Table 2 Chemical composition in weight-%

Steel No.	Q-heat No.	C	Si	Mn	P	S	Cr	Mo	V	N	Bal.
12	9020	0.96	0.81	0.50	0.007	0.005	7.18	2.97	0.41	0.016	Fe
13	9021	0.98	0.95	0.47	0.008	0.005	7.05	2.90	0.41	0.016	Fe
14	9024	0.92	0.93	0.53	0.009	0.005	7.06	2.53	0.40	0.074	Fe
15	9021	0.97	0.91	1.04	0.007	0.005	6.85	2.34	0.41	0.027	Fe
16	9023	1.03	1.06	1.20	0.008	0.005	6.97	1.99	0.66	0.047	Fe
17	9038	0.90	0.84	0.49	0.006	0.005	6.69	2.45	0.44	0.023	Fe
18	9039	0.85	0.86	0.47	0.007	0.004	7.28	2.46	0.43	0.022	Fe

All the heats were forged to the shape of bars, 60 x 60 mm. The material examinations showed that a steel that satisfies the raised requirements best in terms of the different features mentioned in the foregoing should have the following composition in weight-%: 0.82-0.97 C, 0.70-1.10 Si, 0.38-0.62 Mn, at least 7.6 but less than 8.0 Cr, max 0.40 Ni, 2.30-2.70 Mo, max 0.25 W, 0.35-0.55 V, balance iron, impurities and accessory elements in normal amounts. Further, the steel normally contains max 0.15 N, preferably max 0.03 N, max 0.30 Cu, and max 6 ppm H. The Al content must be max

0.1 %, preferably max 0.045 %, but typically it amounts to 0.010-0.045 % as a residual element from the desoxidation treatment of the steel. Typically, the steel should contain 0.92 C, 0.95 Si, 0.5 Mn, 7.8 Cr, 2.5 Mo, 0.45 V.

As far as the micro structure of the steel is concerned, it consists, after austenitising at 1000-1080°C, cooling to room temperature and tempering once or several times at 180-650°C, of tempered martensite, containing a total carbide volume of 3-6 vol-%, preferably 3-5 vol-%, of which 0.25-0.45 vol-% consists of MC carbides and the rest essentially of M_7C_3 carbides. Suitably, the amount of primary carbides is about 4 vol-%.

The steel of the invention can be manufactured in a conventional way through production of a melt, which is cast to ingots, which can be hot worked to the shape of bars, plates, etc., of which there can be made tools or other articles, which can be heat treated for the achievement of a final product having the desired combination of features. The conventional production of ingots can be complemented by any subsequent melt-metallurgical process step, such as e.g. Electro Slag Refining (ESR) or, as an alternative process, the building up of castings of solidifying drops of the melt, such as the process which is known by the name Osprey.

Further characteristics and aspects of the steel of the invention will be apparent from the appending patent claims and from the following description of performed experiments.

BRIEF DESCRIPTION OF DRAWING

In the following description of performed experiments, reference will be made to the drawing, which in a form of a diagram illustrates the punch wear versus the number of strokes in connection with punching ultrahigh strength steel plate.

DESCRIPTION OF PERFORMED EXPERIMENTS

The steel of the invention is intended to be used for the manufacture of tools for cold working. Cold work tools are used e.g. in the automotive industry for blanking, punching, pressing and bending thin steel plates. In this field, new, ultrahigh strength steels have been developed in recent years. One of these steels has been developed by SSAB Tunnplåt AB and is known by its trade name Docol™ 1400 DP and contains, besides iron and unavoidable impurities, in weight-% typically: 0.18 C, 0.50 Si, 1.80 Mn, 0.015 P, 0.002 S, 0.040 A, and 0.030 Nb. This steel is manufactured in gauges between 0.50 and 2.00 mm, in its delivery condition it has the mechanical features stated in Table 3.

Table 3 – Mechanical Properties of Work Material

Steel grade	Yield strength $R_{p0.2}$ or R_{eL} N/mm^2 min.-max.	Yield strength after 2 % deformation and bake hardening 170°C/20 min Rp2.0+BH N/mm^2 min.	Tensile strength R_m N/mm^2 in transverse direction min.-max.	Elongation A_{80} % min.	Min. radius for 90° bend
Docol(TM) 1400 DP	1200-(1450)	1350	1400-1600	3	4.0 x thickness

Details in side impact protect systems, bumper reinforcements, seat frames and beams and other structural parts in motor cars are typical applications of this steel. The performed investigations aimed at evaluating the feasibility of the steel for tools for the manufacture of products of the said kind and at comparing the features of the steel with other, commercially available steels for cold work tools.

The chemical compositions of the examined steels are listed in Table 4. Steel No. 19 is a steel of the invention. The steel was manufactured as a 35 tons production heat in an electric arc furnace. Of the steel there were cast ingots, which were forged and rolled to the shape of bars. The contents of nickel, niobium, titanium, and copper are residuals from used raw materials and are unintentional. Aluminium has been added for the desoxidation of the steel, and the stated content of aluminium is a residue from that process. Steel No. 20 is a steel according to the above mentioned US-A-5,160,553, which has been manufactured by another producer. The steel, which is commercially available, has been analysed by the applicant with reference to its chemical composition. Steels Nos. 21, 22, and 23 are commercial steels, which are manufactured by the applicant. The contents of steels Nos. 21-23 stated in Table 4 are nominal contents. Steel No. 21 is a conventionally manufactured steel, while steels Nos. 22 and 23 have been manufactured powder metallurgically. Besides the contents of the different elements stated in the tables, these steels also contain impurities in normal amounts eminating from the raw materials which were used for the manufacture of steel.

Table4 – Chemical composition, weight-%

Steel No.	C	Si	Mn	P	S	Cr	Ni	Mo	W	V	Nb	Ti	Cu	Al	N	O	Bal.
19	0.91	0.9	0.52	0.021	0.0007	8.07	0.12	2.59	0.036	0.48	0.002	0.006	0.69	0.025	n.a.	n.a.	Fe
20	1.06	0.79	0.39	0.021	0.0001	8.85	0.22	2.19	0.091	0.51	0.14	0.0052	0.07	0.891	n.a.	n.a.	Fe
21	1.55	0.3	0.3	≤0.030	≤0.030	12.0		0.8		0.8							Fe
22	1.5	1.0	0.4	≤0.02	≤0.015	8.0		1.5		4.0							Fe
23	2.07	1.0	0.4	≤0.02	≤0.015	6.8		1.5		5.35							Fe

n.a. = not analyzed

Punches with the punch diameter 10 mm were manufactured of bars of steels Nos. 19-23. The bar dimensions are listed in Table 5. All punches were taken out from the centre of the bars and cross-wise the bar direction, the longitudinal direction of the punch coinciding with the height direction of the bar. The working material consisted of said Docol™ 1400 DP with a thickness of 1.0 mm. The material was cold rolled and heat treated for the achievement of highest strength level and it therefore gave a good indication concerning abrasive wear resistance and ductility/toughness. The punching operatings were carried out in a 15 tons excenter press. The punching rate was 200 strokes/min; punching play 6 %; no lubrication. The measurement of the wear was made by means of a prism, the curve deviation being measured before and after the punching series. The difference was transformed to number of μm^2, which represents the wear.

Table 5 shows the testing parameters and the registered punch wear after 200,000 punching strokes. The table also shows the heat treatment of the tools. All the tools had been hardened from the stated austenitising temperature (T_A as is shown in the table) and tempered twice after cooling, each time for two hours at the tempering temperature given in the table.

Table 5

Steel No.	Punch wear (μm^2)	Bar dimension (mm)	Hardness (HRC)	Heat treatment
19	13125	254x76.2	60	T_A=1030°C/30 min+ 550°/2x2h
20	36105	200x100	59.5	T_A=1050°C/30 min+ 550°/2x2h
21	18743	250x80	60,5	T_A=1020°C/30 min+ 550°/2x2h
22	9618	250x80	60	T_A=1020°C/30 min+ 525°/2x2h
23	7790	250x63	60.5	T_A=1020°C/30 min+ 525°/2x2h

In the drawing, the wear during the course of the complete punching test is shown. The results can be explained in the following way. The powder metallurgically manufactured steels Nos. 22 and 23 have sufficient ductility to avoid microchipping of the punch edge, and the smallest abrasive wear stated for steel No. 23 is due to the higher vanadium content in that steel. Steel No. 19 of the invention, which has a well

balanced chemical composition of alloy elements, also has a balanced combination of features, where abrasive wear dominates over microchipping of the punch edge. The wear resistance was better than that of the substantially higher alloyed steel No. 21 and was comparable with that of the exclusive, powder metallurgically manufactured steels Nos. 22 and 23, which contained high vanadium contents. Especially, steel No. 20 had a pronounced tendency to microchipping of the punch edge, which explains why that material is less good in this test.

CLAIMS

1. Cold work steel, c h a r a c t e r i s e d in that it has the following chemical composition in weight-%:
0.82-0.97 C
from traces to max 1.10 Si
from traces to max 0.62 Mn
at least 7.6 but less than 8.0 Cr
2.30-2.70 Mo
0.35-0.55 V
balance iron and impurities in normal amounts in the form of residual elements from the manufacture of the steel.

2. Cold work steel according to claim 1, c h a r a c t e r i s e d in that it contains at least 0.70 Si and at least 0.38 Mn.

3. Cold work steel according to claim 1, c h a r a c t e r i s e d in that it contains max 0.25 W.

4. Cold work steel according to claim 1, c h a r a c t e r i s e d in that it contains max 0.40 Ni.

5. Cold work steel according to claim 1, c h a r a c t e r i s e d in that it contains max 0.15 N, preferably max 0.03 N.

6. Cold work steel according to claim 1, c h a r a c t e r i s e d in that it contains max 0.30 Cu.

7. Cold work steel according to claim 1, c h a r a c t e r i s e d in that it contains 0.85-0.95 C.

8. Cold work steel according to claim 1, c h a r a c t e r i s e d in that it contains 0.46-0.54 Mn.

9. Cold work steel according to claim 1, c h a r a c t e r i s e d in that it contains 2.40-2.60 Mo.

10. Cold work steel according to claim 1, c h a r a c t e r i s e d in that it contains 0.4-0.5 V.

11. Cold work steel according to claim 1, c h a r a c t e r i s e d in that it contains 0-0.1 Al, preferably max 0.045 Al, suitably 0.010-0.045 Al.

12. Cold work steel according to claim 1, c h a r a c t e r i s e d in that it contains 0.92 C, 0.95 Si, 0.5 Mn, 7.8 Cr, 2.5 Mo, 0.45 V.

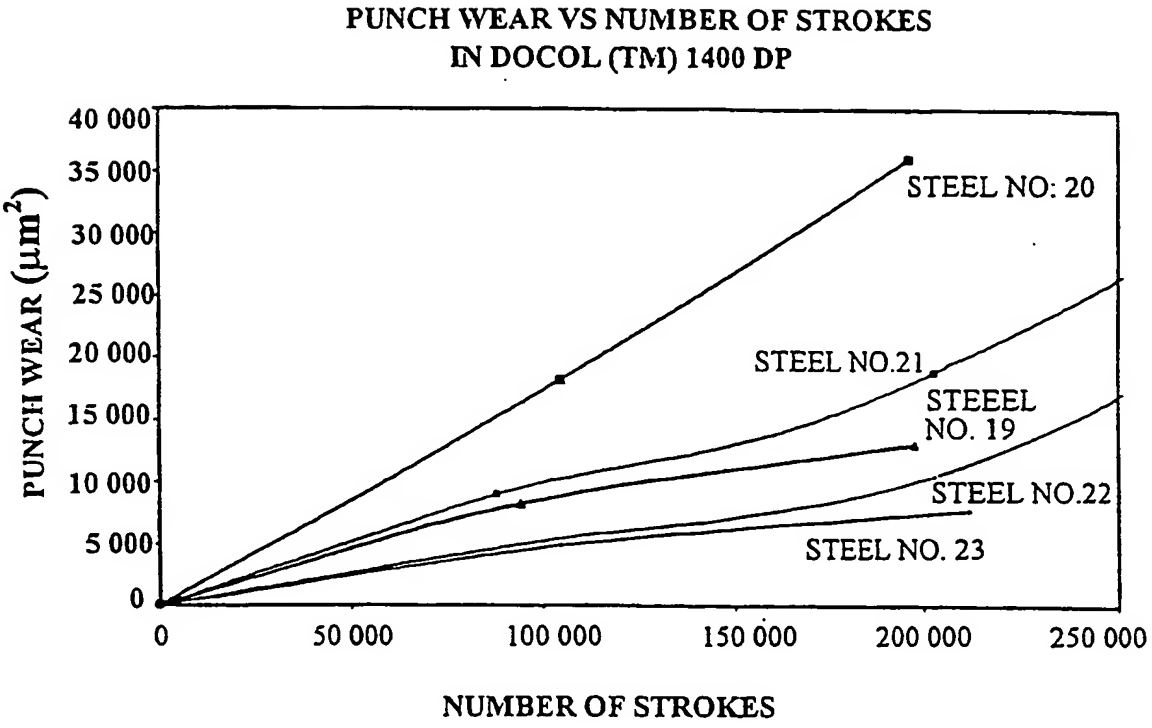
13. Cold work steel according to any of the claims 1-12, c h a r a c t e r i s e d in that it after austenitising at 1000-1080°C, cooling to room temperature and tempering once or several times and 180-650°C contains 3-6 vol-% carbides, preferably 3-5 vol-% carbides, thereof 0.25-0.45 vol-% MC carbides and the rest essentially M_7C_3 carbides.

14. Use of a cold work steel according to any of the claims 1-13 for the manufacture of cold work tools.

15. Use according to claim 14 for blanking, punching or forming sheet metal.

16. Use according to claim 14 for working constructional elements, preferably steel sheets.

17. Use according to claim 14 for working sheet metal for construction elements within the automotive industry, white goods industry and the electronic industry.


PUNCH WEAR VS NUMBER OF STROKES
IN DOCOL (TM) 1400 DP
PUNCH WEAR (µm²)
40 000
35 000
30 000
25 000
20 000
15 000
10 000
5 000
0
0
50 000
100 000
150 000
200 000
250 000
NUMBER OF STROKES
STEEL NO: 20
STEEL NO.21
STEEEL NO. 19
STEEL NO.22
STEEL NO. 23

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/00346

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: C22C 38/24
According to International Patent Classification (IPC) or to both national classification and IPC

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Minimum documentation searched (classification system followed by classification symbols)

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EDOC, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5160553 A (KARL LEBAN ET AL), 3 November 1992 (03.11.92), claim 6 ---	1-17
A	SE 456650 B (UDDEHOLM TOOLING AB), 24 October 1988 (24.10.88), claim 1 --- --------	1-17

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT.

Information on patent family members

01/06/99

International application No.
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